AIR QUALITY BALMERTOWN

Annual Report, 1976

Ministry
of the
Environment
Ontario

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ONTARIO MINISTRY OF THE ENVIRONMENT

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CONTENTS

SUMMARY

An air quality assessment programme, begun in 1971 at Balmertown by Ontario Ministry of the Environment, continued in 1976 with vegetation and soil sampling, snow sampling and air monitoring operations. Investigations were centred in the vicinity of two gold mines, whose roaster stack discharges constituted the principal local industrial sources of air pollution.

Evaluation of crowns of trembling aspen trees in 11 observation plots for a 3-year period provided some evidence of decline, but no relationship was established between declining crown condition and roaster stack emissions. In contrast to other years, and despite continued sulphur dioxide emissions, there were no symptoms of acute sulphur dioxide injury observed on foliage of any plant species in 1976. Disappearance of arsenic injury to vegetation in 1976 was attributed to sharply reduced arsenic emissions. Moderately elevated concentrations of arsenic, iron, and sulphur were found in trembling aspen foliage near the mines. Arsenic levels were the lowest since surveys began in 1972, but were still above desirable concentrations at some sites. Excessive arsenic content was found in surface soil, but average concentrations had decreased moderately from 1975 and earlier years. Mercury contamination of soil was found just outside the plant area at Campbell Red Lake Mines, but the specific source was not identified.

The trend of declining arsenic levels, reported for forest vegetation and soils, was also found in planted roadside trees, garden vegetables, and garden and lawn soils. However, the arsenic content of some samples of edible vegetables still exceeded the acceptable limit set by the Canada Health Protection Branch.

The presence of arsenic, iron, and mercury contamination near the Balmertown gold mines was demonstrated from a snow sampling survey.

Arsenic in dustfall at four Balmertown monitoring sites was low. Sulphation rates, a measure of the presence of sulphur-containing

gases, were above the Ontario criterion on 10 occasions at four sites in 1976. Elevated sulphation rates were also recorded near the mines during a special mid-summer survey.

The Ontario criteria for hourly and daily average sulphur dioxide concentrations were exceeded on a number of occasions in 1976. Wind direction data implicated the gold mine roaster stacks as emission sources.

INTRODUCTION

Air quality investigations by Ontario Ministry of the Environment began in 1971 in Balmertown to assess the effects of airborne emissions from operations at two local gold mines. Both firms, Campbell Red Lake Mines Limited and Dickenson Mines Limited, use an ore roasting process which, for more than 25 years, discharged waste gases containing substantial quantities of arsenic and sulphur dioxide. In early 1974, arsenic emission controls were installed in Campbell's mill. At Dickenson, the installation of similar equipment is nearing completion. In the meantime, the Company agreed to suspend roasting when winds dispersed smoke from the roaster stack over the town area. The roaster was also shut down for the entire 1976 growing season (May to October) while pollution control equipment was being installed. Control programmes at both mines, when fully implemented, will result in almost total elimination of arsenic discharges to the air. Sulphur dioxide emissions will continue with little significant change.

Results of Ministry studies at Balmertown for the period 1971 to 1975 are contained in the 1975 Balmertown air quality report (1). This work included assessment of the crown condition of trees in observation plots, vegetation, soil and snow sampling, and operation of a small air monitoring network. Most features of the 1975 programme continued in 1976. In addition, a continuous sulphur dioxide monitor was installed in Balmertown Public School in late January, 1976. For a brief period in July, data from this instrument were telemetered to Toronto as part of a Canada-wide Communications Technology Satellite experiment.

VEGETATION AND SOIL ASSESSMENT

(a) Forest Areas

(i) Observation Plots

Sixteen trembling aspen (*Populus tremuloides*) observation plots, 14 near Balmertown and two controls to the south, were first established

in 1974. Eleven of the 16 (Figure 1) were maintained in 1976. The crown condition of trees in each plot was assessed in late August using a Canadian Forestry Service crown classification system, which ranked trees into several classes based on the presence and extent of crown dieback. Tree foliage and stems were also inspected for evidence of air pollution injury, insect attack or disease problems. Tree diameters and heights were measured in October.

Rankings of crown classes (Table 1) showed that about 81 percent of the trees were apparently healthy, 13 percent exhibited some degree of dieback, and 6 percent were dead. The highest incidence of dieback occurred at plot 5, about mid-way between the two mines. Changes in crown condition since 1974 (Table 2) also shows that the greatest rate of decline was found at plot 5. Trees in this plot grew more slowly in diameter than those in other parts of the survey area (Table 3). However, because of the short period of observation (three growing seasons) and the possible influence of other factors (stand density, site, insects, disease) no conclusions could be reached concerning the effect of roaster emissions on the health and growth of young aspen stands near the mines.

Since tree height is not a sensitive indication of growth over short periods of time, no height data will be reported until 1978.

The most noteworthy insect injury was caused by an infestation of forest tent caterpillar (*Malacosoma disstria*). Substantial defoliation by this insect was noted in early July, but most trees had recovered by late August, when defoliation severity was judged to be light. The level of tent caterpillar injury was not related to distance from either mine. Some leaf-spot diseases caused by fungi were also observed, but none of these were associated with significant damage at any location.

(ii) Air Pollution Injury

Acute injury symptoms, typical of airborne arsenic and sulphur dioxide, were noted on vegetation near the Balmertown gold mines in 1972 and 1973. Arsenic injury was much reduced in 1974 following the installation of arsenic emission control equipment at Campbell Red Lake Mines earlier that year. This improvement continued in 1975 with better

dispersion of arsenic through a new, taller roaster stack brought into service at Dickenson Mines in June, 1975. During the same period (1972 to 1975) sulphur dioxide vegetation injury was commonly observed near both mines. In 1974 and 1975, the area containing vegetation with sulphur dioxide injury symptoms was estimated to be 60 ha (hectares).

In 1976, no injury caused by arsenic or sulphur dioxide could be found on vegetation in the Balmertown area. The absence of arsenic injury was expected but the lack of SO_2 damage was not. Air monitoring data (see following sections) indicated the occurrence of a number of potentially injurious sulphur dioxide fumigations during the growing season. However, sulphur dioxide emissions were lower in 1976 than preceding years due to the shut-down of Dickenson's roaster from May to October. Also, rainfall was low (65 percent of normal) during the prime growing months of June, July and August, and this condition may have led to increased resistance of vegetation to air pollution injury.

(iii) Chemical Analysis of Vegetation and Soil

Sampling surveys of plant foliage and soil in 1972 and 1973 demonstrated the presence of an area of arsenic contamination near the Balmertown gold mines and clearly established that this contamination was caused by the deposition of airborne arsenic. Sharp decreases in the arsenic content of forest vegetation in 1974 and 1975 were attributed principally to the implementation of an arsenic emission abatement programme at the Campbell mine. Arsenic levels in soil remained high. Iron and sulphur concentrations in forest tree foliage were also elevated, but the mercury and lead content of soil was low.

In 1976, triplicate samples of trembling aspen foliage and surface soil (0-5 cm) were collected in late August from the same 26 sites sampled in 1975 (Figure 1). In a separate survey, surface soil from 14 locations (including two controls) was sampled for mercury analysis. Each foliage sample comprised about 500 g (grams) of fresh leaf material placed in a labelled, perforated polyethylene bag and transferred to refrigerated storage pending air shipment to processing and analytical facilities in Toronto. Soil was obtained with a stainless steel corer,

2.5 cm (centimetres) in outside diameter. Surface debris and organic matter above the soil was removed prior to each insertion of the corer. At least 10 cores were pooled to form one composite sample which was placed in a labelled plastic bag for shipment. Before analysis, vegetation samples were oven-dried and ground in a Wiley mill. Soil was air-dried for 48 hours, then coarse-screened to remove stones and organic matter. Final screening was through an 80-mesh sieve. Following digestion in a mixture of nitric and perchloric acid, anyalysis for arsenic and iron content of plant and soil material was by atomic absorption spectroscopy. Mercury was determined by ultraviolet spectrophotometry and sulphur by an x-ray diffraction technique.

Table 4 presents chemical analysis results for arsenic, iron, and sulphur in trembling aspen and soil. The data show that arsenic concentrations in aspen leaves were elevated near the mines and declined with increasing distance from both sources. Eight of the 26 values were above the guideline of 10 ppm (parts per million) currently applied in Ontario, and the highest concentration was found near Dickenson Mines. Iron and sulphur levels followed the same general distribution pattern as arsenic, although the centre of highest sulphur concentrations was farther to the west than that for the other two contaminants. Iron and sulphur levels were not considered to be excessive. The arsenic content of surface soil was above the guideline (40 ppm) throughout most of the survey area, with greatest contamination centred between the two mines.

In Figures 2a and 2b, arsenic in trembling aspen is compared for 1975 and 1976. There is a clear indication of a significant decrease in the area and severity of contamination in 1976. Average arsenic levels in aspen foliage declined about 77 percent from 1975 to 1976. Lesser decreases, 57 and 28 percent, were registered for iron and sulphur concentrations, respectively. Arsenic in soil also showed some evidence of decrease, contrary to expectation.

Though the arsenic content of vegetation decreased significantly from 1975 to 1976, a greater improvement had been expected with virtual total cessation of airborne arsenic emissions. To determine whether aspen trees may have translocated arsenic from soil to foliage, hot water

extracts from soil at selected sites were subjected to arsenic analysis. Results are summarized in Table 5. The data show that substantial amounts of arsenic could be extracted from some samples, but that extractibility was not related to either total arsenic in soil or to the arsenic content of foliage.

A 5-year comparison of arsenic levels in aspen leaves is shown in Table 6. Concentrations in 1976 were lower than those for any other year.

Results of the special mercury survey are plotted in Figure 3. There was a definite indication of mercury contamination in soil close to the Campbell Red Lake plant area. The highest concentration recorded was 12 ppm. Further investigation will be required to determine whether contamination arose from airborne deposition. Both mines use mercury in their ore processing operations, but mercury losses to atmosphere have never been considered significant.

(b) Planted Roadside Trees

Arsenic analysis results for 1976 for Manitoba maple (*Acer negundo*) and white elm (*Ulmus americana*) foliage at three sites in Balmertown are shown in Table 7, along with comparable data for earlier years. In 1973, 1974, and 1975, arsenic content in leaves from the side of trees facing the mines was significantly higher than that from the side of trees away from the source, thereby confirming the presence of airborne contamination. In 1976, except for one site, the difference between facing and away from source had largely disappeared and the arsenic concentrations had fallen to much lower levels than those reported for preceding surveys. Sulphur and iron concentrations were similar for sides of trees facing and away from the sources and were about the same as levels for control samples from the town of Red Lake.

(c) Vegetable Gardens

Of the three contaminants investigated in Balmertown garden vegetation, only arsenic has been considered a potential threat to human

health. In 1976, arsenic levels in assorted garden vegetables were lower than those of earlier years (Table 8) but a few samples still exceeded the maximum acceptable limit of 1.0 ppm, fresh weight, set by Canada Health Protection Branch. Of three Balmertown gardens sampled, arsenic in beet leaves from one garden was just over the limit at 10.6 ppm, dry weight (about 1.1 ppm, fresh weight). Slightly higher levels were found in washed lettuce in two of the three gardens, where average concentrations of 14.0 and 14.6 ppm, dry weight (about 1.4 and 1.5 ppm, fresh weight) were recorded. Arsenic in garden and lawn soils continued to be well above the desirable level, although there was evidence of slow improvement. At one residence on Fifth Street, for example, the arsenic decreased from 170 to 119 ppm in garden soil and from 715 to 364 ppm in lawn soil between 1974 and 1976.

SNOW SAMPLING

In 1974 and 1975, snow sampling surveys in the Balmertown area revealed the presence of elevated concentrations of arsenic, iron and sulphate near the gold mines. Arsenic demonstrated the most pronounced gradient of decreasing concentration with increasing distance. Highest arsenic levels occurred just east of Dickenson Mines, which was implicated as the primary emission source.

Further snow sampling was conducted in late January, 1976, at 24 Balmertown sites plus two controls (Figure 4). Sample points were selected in undisturbed snow, with preference for areas sufficiently open to permit the free fall of snow but not subject to excessive drifting. Areas thought to be affected by contaminants from roads or other extraneous sources were avoided. Each site was mapped, and information was recorded on site description, snow condition and snow depth. The kind and amount of visible particulate contamination on and below the snow surface was also noted. Each sample comprised a surface area of about 50 by 50 cm (centimetres) and a depth of 20 cm. Snow was collected with a clean plastic shovel, placed in large, heavy-gauge polyethylene bags, and retained in unmelted condition until processed. Samples were then melted

indoors in clean plastic pails pre-rinsed with distilled water. Measurement of pH was made when melting was completed (usually 12 to 18 hours). Meltwater was then vigorously stirred to suspend particulate matter, and decanted into clean, 1-litre plastic bottles for submission to the Ministry's Thunder Bay Regional Laboratory. Analysis for iron was conducted by an orthophenanthroline method, for mercury by flameless atomic absorption spectroscopy, and for arsenic by the silver diethyldithiocarbamate method.

Contaminant concentrations from the 1976 survey are summarized in Table 9. Mercury, plotted in Figure 5, demonstrated a pronounced distribution pattern which suggested airborne deposition from one or both mines. At two locations (sites 8 and 9), concentrations were similar to those found near a mercury-cell chlor-alkali plant in northwestern Ontario (2). The levels of mercury recorded were not anticipated, and the reason for their presence has not been clearly established. Arsenic and iron exhibited distribution patterns (Figures 6a and 6b) similar to one another but different from that for mercury. Values for pH were uniformly low throughout the survey area and at both controls. No significant quantity of visible particulate matter was seen at any site. Fresh snow (that which fell in the 10-day period before sampling) comprised about 60 percent of each sample. Average total snow depth was 41 cm.

AIR MONITORING

(a) Dustfall

Dustfall, one of the most visible classes of air pollutants, comprises particulate matter which settles out from the atmosphere under the influence of gravity. It is measured by exposing open-top vessels for 30 days and weighing the collected matter. Results are expressed in tons per square mile per month. Soluble and insoluble components of dustfall may also be separately determined: Balmertown dustfall was analysed for sulphate and arsenic content.

Total dustfall and soluble sulphate in dustfall is given in Table 10 for the four monitoring sites in use during 1976 (Figure 7).

Many measurements were invalidated because of contamination by bird droppings and other organic debris. Station 61012 was especially prone to this problem. Some values were above Ontario criteria, but these were not attributed to emissions from local industry. Sulphate levels were low. Arsenic levels (Table 11) were well below the guideline of 4 pounds per acre per year.

(b) Sulphation Rates

Sulphation rate is measured by exposing small plastic plates or tubes (candles) coated with lead dioxide to the atmosphere for 30-day periods. Lead dioxide reacts with gaseous sulphur compounds to form lead sulphate. The quantity of sulphate formed is analytically determined and reported as milligrams of sulphur trioxide per hundred square centimetres per day (mg SO_3/100 cm^2/day). The method is normally used to detect sulphur dioxide, but other reactive sulphur compounds, such as hydrogen sulphide, may also be converted to the sulphate form. In Balmertown, sulphur dioxide is the only reactive compound present in significant quantity.

Sulphation plate exposure results are summarized in Table 12. Highest values were recorded at station 61010, where the Ontario criterion was frequently exceeded. Lowest averages were measured at stations 61012 and 61013, locations which would less frequently be downwind of either mine than stations 61010 and 61011, where much higher averages were found. Sulphation rates in 1976 were higher than those for 1975 at all locations.

In a special, mid-summer survey, sulphation plates were exposed at 15 sites around the two mines. The results obtained (Figure 8) were about as expected, and show that highest sulphation rates were centred between the two mines. A similar survey in 1975 yielded about the same results.

(c) Sulphur Dioxide

Fuel combustion and industrial emissions are significant man-made sources of sulphur dioxide (SO_2), one of the world's major atmospheric

pollutants. The adverse effects of SO_2 on human health, vegetation, and corrosion of building materials are well documented. In Balmertown, emissions from roaster stacks at the two gold mines are the principal local industrial sources of SO_2. Total daily emissions, with both roasters operating, are in the range of 25 to 30 tons.

Sulphur dioxide monitoring at Balmertown began in late January, 1976, with the installation of a Davis model 7010 RPL continuous analyzer in Balmertown Public School. Since this instrument operates on the principle of conductivity, a certain amount of data was lost because of the presence of interfering gases, principally carbon dioxide. In June, the Davis was replaced with a Philips model PW 9755. This monitor, operating on the principle of continuous coulometric titration, is not subject to interferences. However, instrument malfunction resulted in loss of data, particularly toward the end of the year. In an experiment utilizing a Communications Technology Satellite, data for several days in July were telemetered from Balmertown to Red Lake and thence from Red Lake to Toronto via satellite (3). There was good agreement between SO_2 values reported by satellite and those recorded in the normal way on strip charts.

During 1976, the hourly criterion for SO_2 (0.25 ppm) was exceeded 78 times. The maximum hourly reading was 0.54 ppm. Average concentrations above the daily criterion (0.10 ppm) were recorded twice in May, once each in June and July, and twice in September. The annual average, 0.016 ppm, was below the Ontario criterion of 0.20. Table 13 summarizes the data for six SO_2 concentration categories.

The specific source of each fumigation was not always easy to establish. Wind directions at Balmertown may have sometimes differed from those 5 km (kilometres) to the west-northwest at Cochenour where wind measurements were made. Also, wind direction records were based on an estimate of average direction during 1-minute observation periods each hour. Wind direction between hourly observation intervals was not reported. Finally, wind direction was given for only eight points of the compass rather than the more sensitive 16-point system in use at larger weather stations. Based on available wind direction data, wind

and pollution roses were constructed (Figure 9). Pollution roses implicated the gold mines as the sole SO_2 sources but could not distinguish between one mine and the other. During 1976, however, Dickenson's roaster was shut down from May 15 to October 5. All above-criteria hourly SO_2 concentrations during this period (45 of the 78 recorded for the year) were therefore attributed to emissions from Campbell Red Lake.

ACKNOWLEDGEMENTS

Contributions and assistance from the following agencies are gratefully acknowledged:

- Air Quality Laboratory Section, Laboratory Services Branch, for preparing and analyzing sulphation plates, and for analyzing vegetation and soil samples.
- Thunder Bay Laboratory, Northwestern Region, for determining total dustfall, sulphate and arsenic content of dustfall, and for analyzing snow meltwater.
- Northern Affairs Branch, Ministry of Natural Resources, for operating the Balmertown air quality instrument network.
- Air Quality and Meteorology Section, Air Resources Branch, for processing SO_2 data and for calibrating the SO_2 monitor.
- Phytotoxicology Section, Air Resources Branch, for processing vegetation and soil samples.
- Board of Education, Red Lake, for permission to install monitoring equipment in Balmertown Public School.

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1. Griffin, H. D. (1976). Air Quality-Balmertown. Annual Report, 1975. Ontario Ministry of the Environment.

2. Ontario Ministry of the Environment (1977). Air Quality-Marathon. Annual Report, 1976.

3. Jain, N. K. (1976). Report on Communication Technology Satellite - Experiment P301. Ontario Ministry of the Environment.

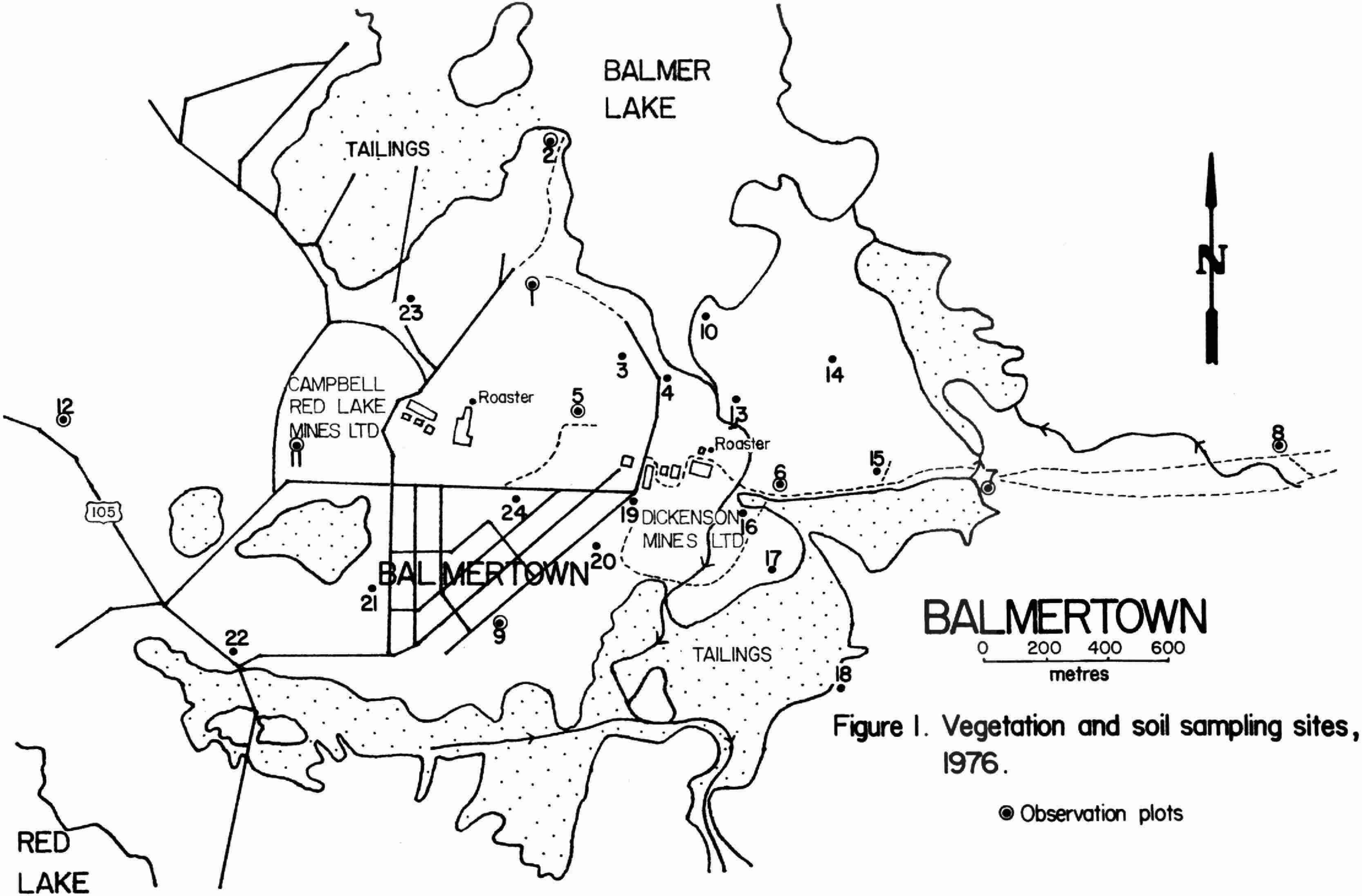

Figure I. Vegetation and soil sampling sites, 1976.

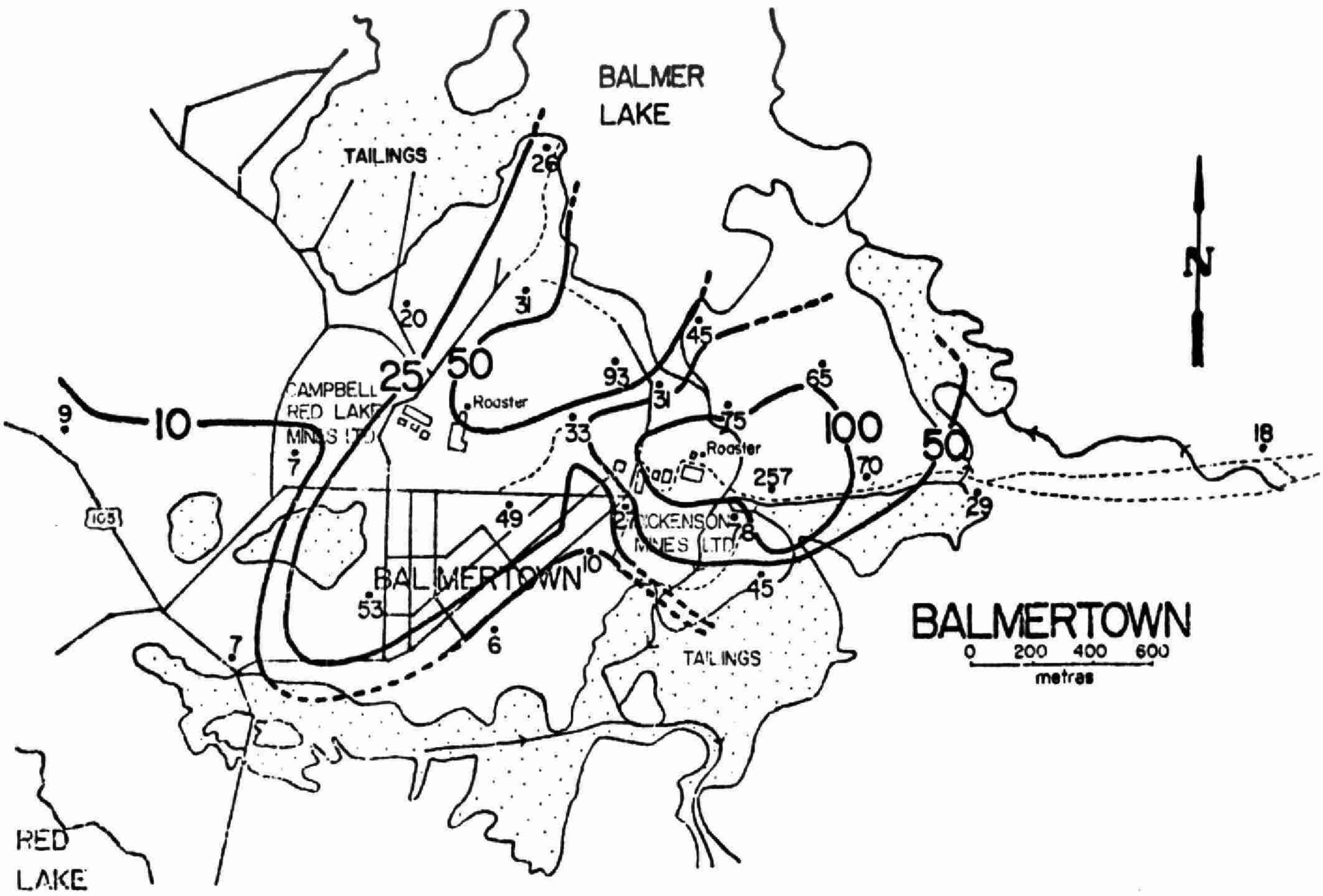

Figure 2a. Arsenic concentrations (µg/g) in trembling aspen foliage, September, 1975.

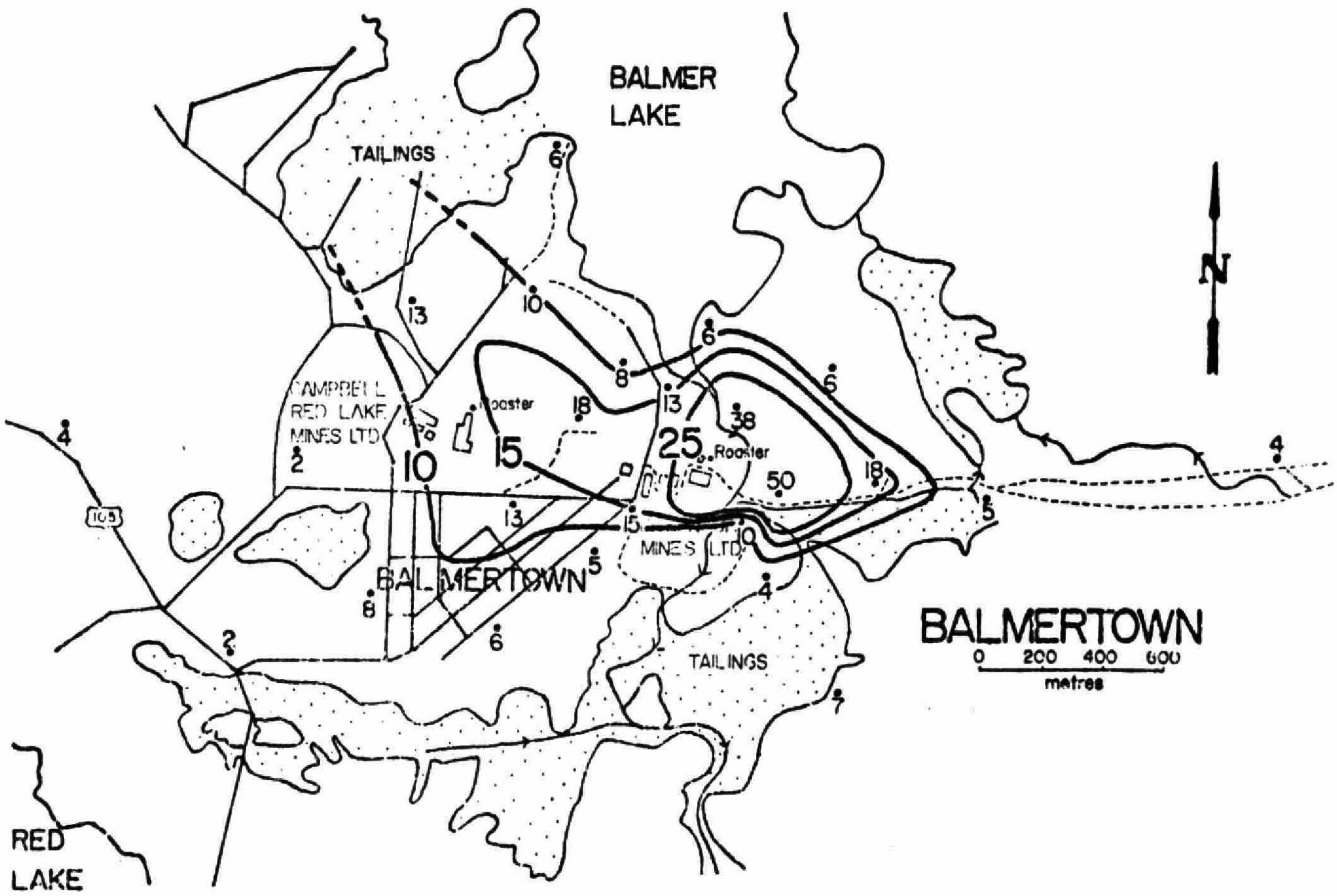

Figure 2b. Arsenic concentrations (µg/g) in trembling aspen foliage, September, 1976.

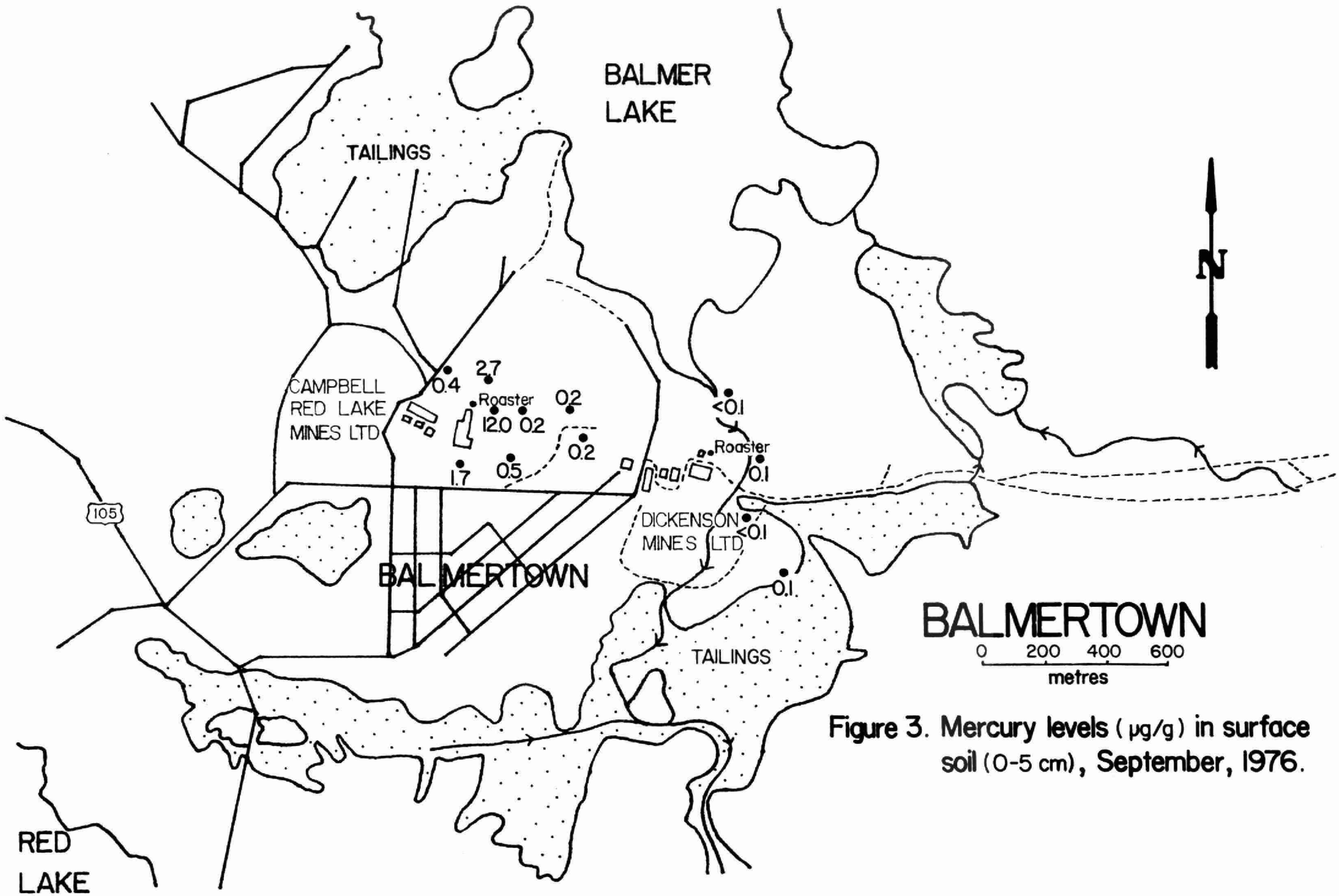

Figure 3. Mercury levels (µg/g) in surface soil (0-5 cm), September, 1976.

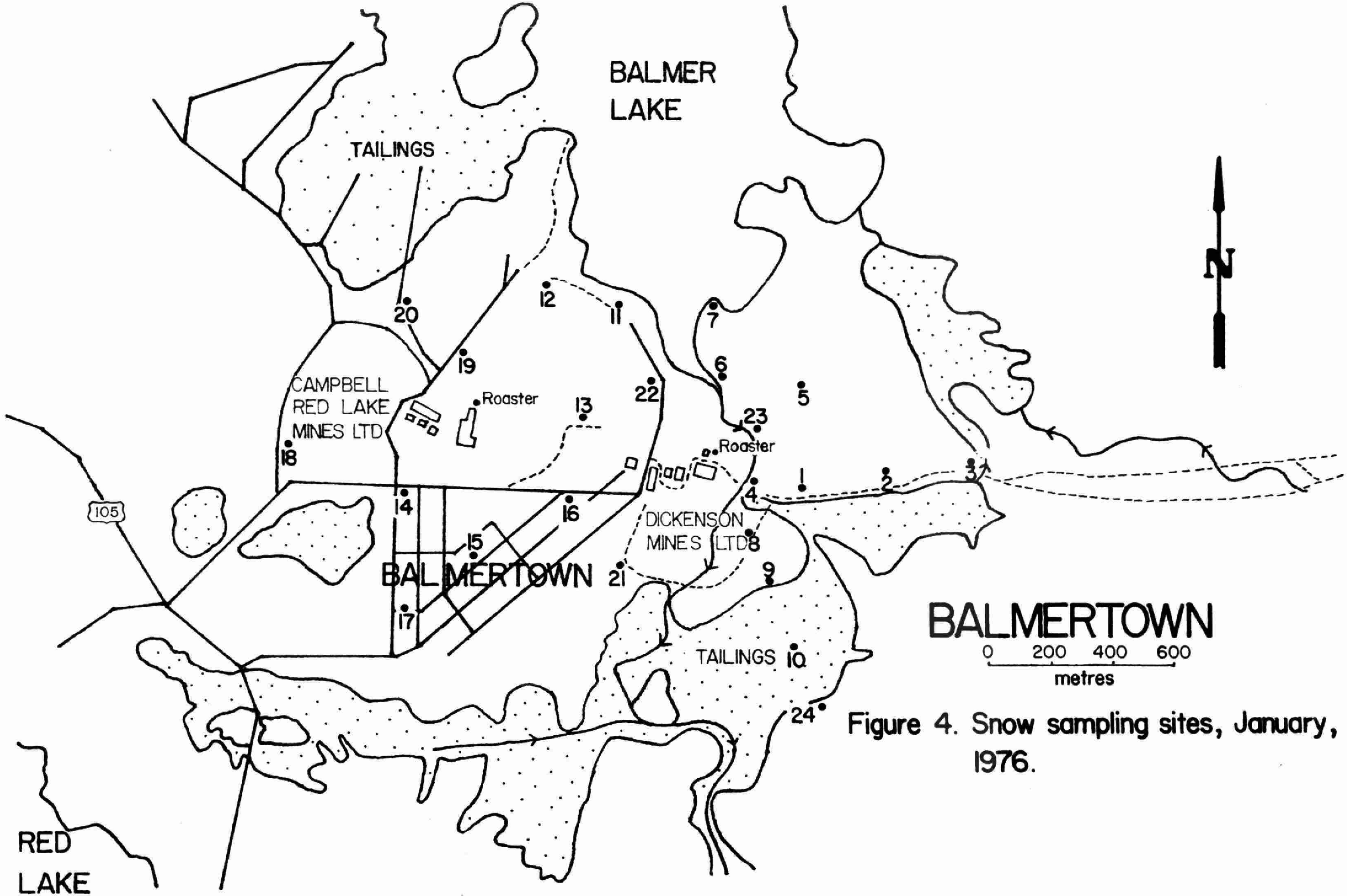

Figure 4. Snow sampling sites, January, 1976.

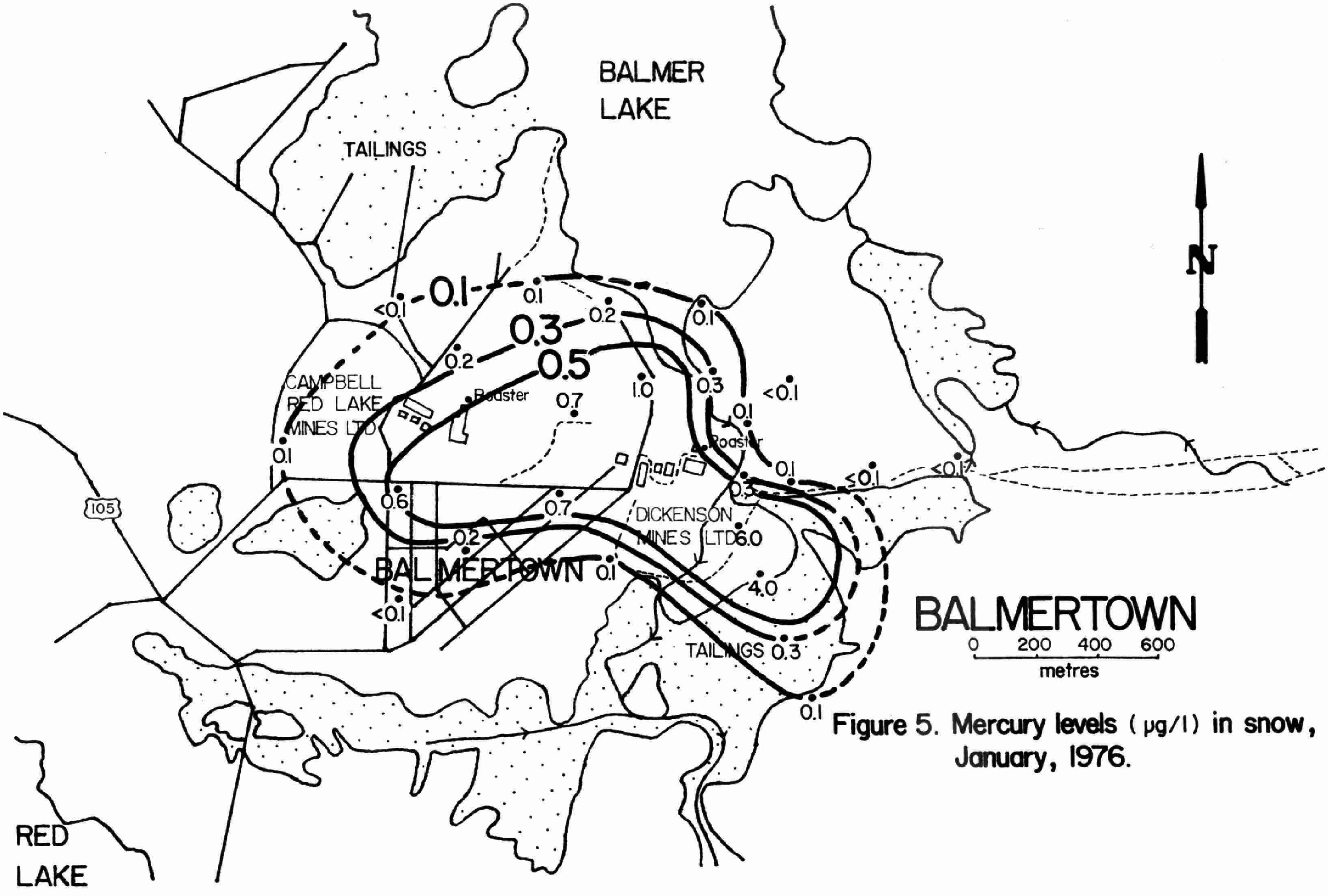

Figure 5. Mercury levels (μg/l) in snow, January, 1976.

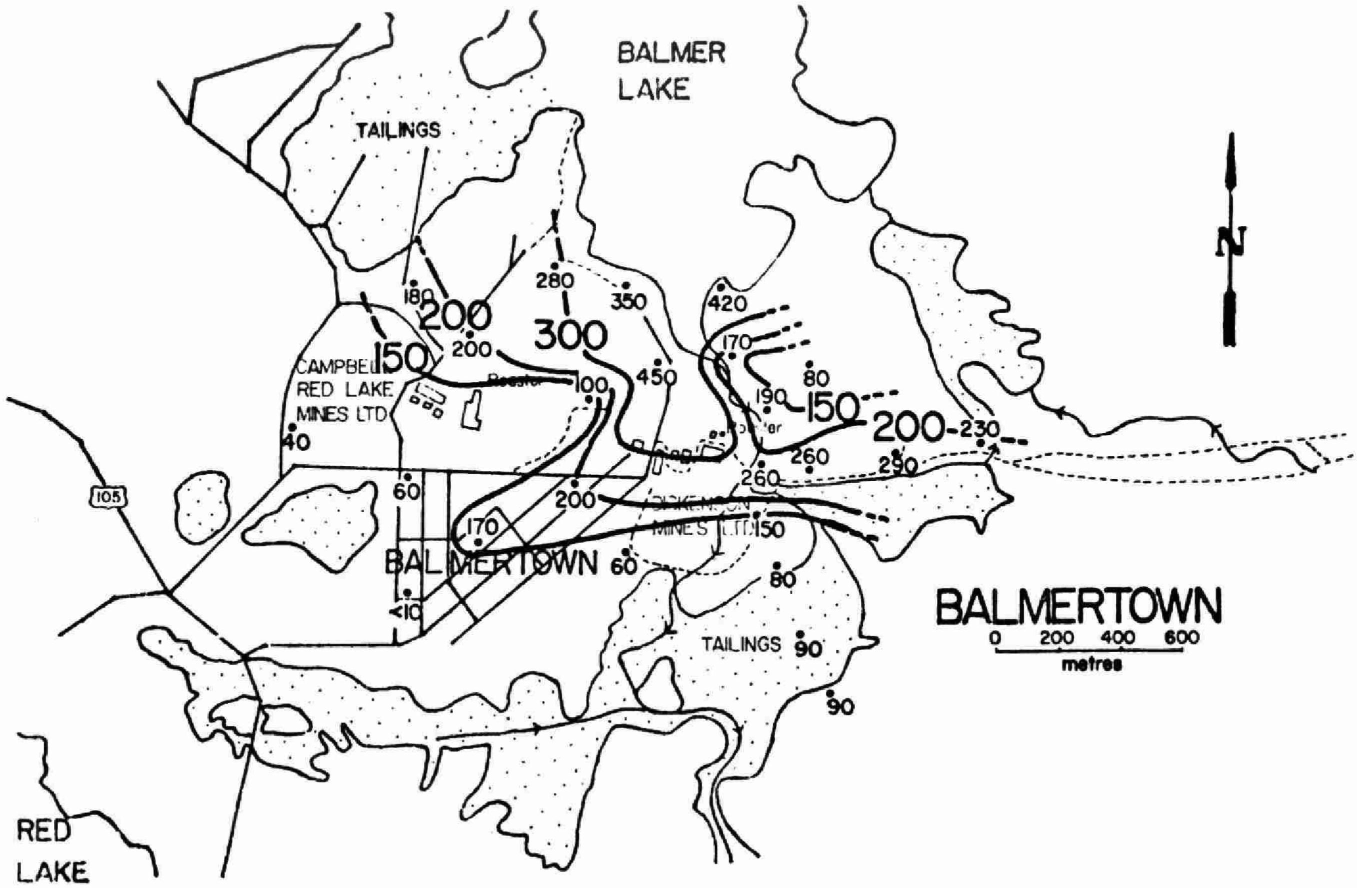

Figure 6a. Arsenic levels (µg/l) in snow, January, 1976.

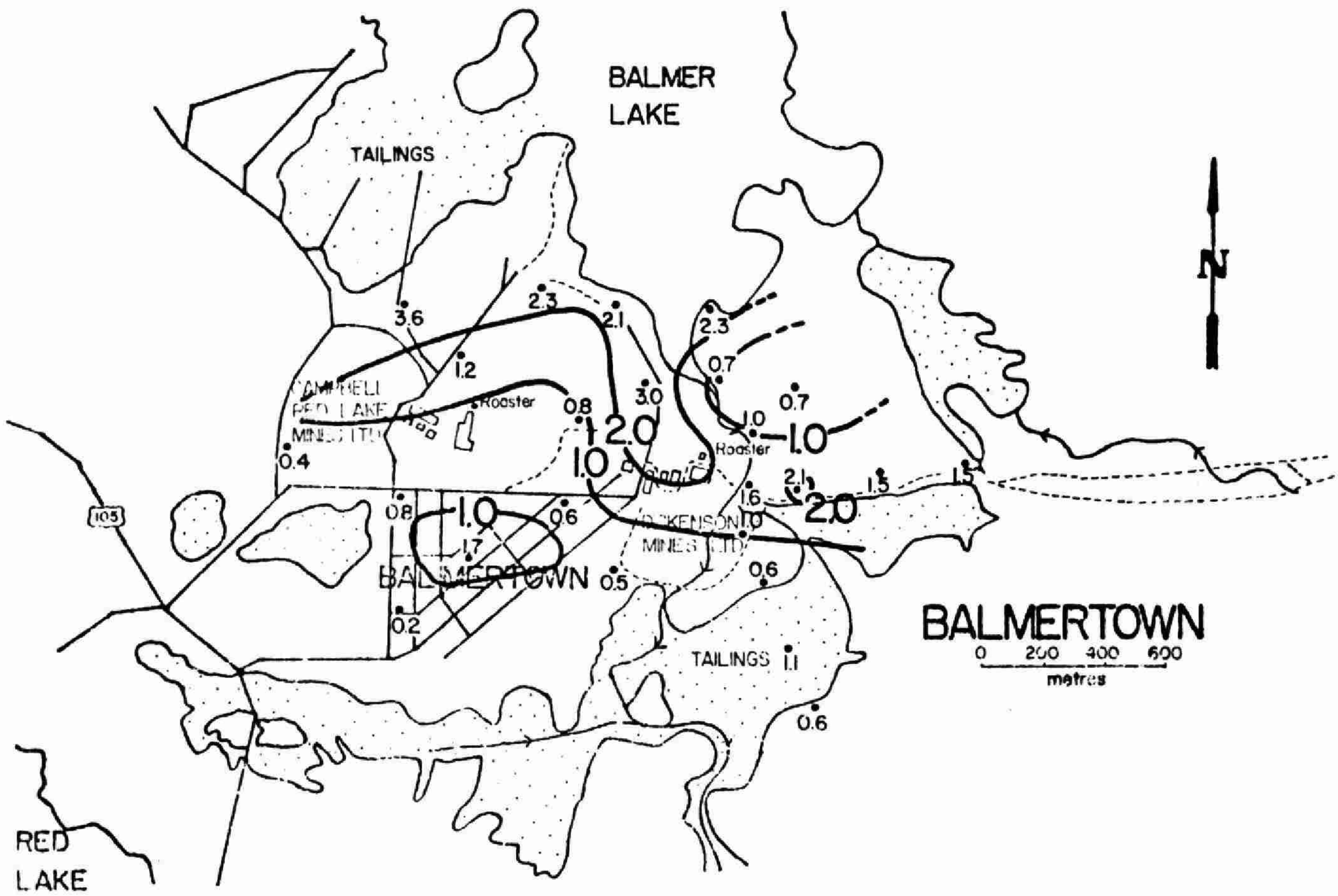

Figure 6b. Iron levels (mg/l) in snow, January, 1976.

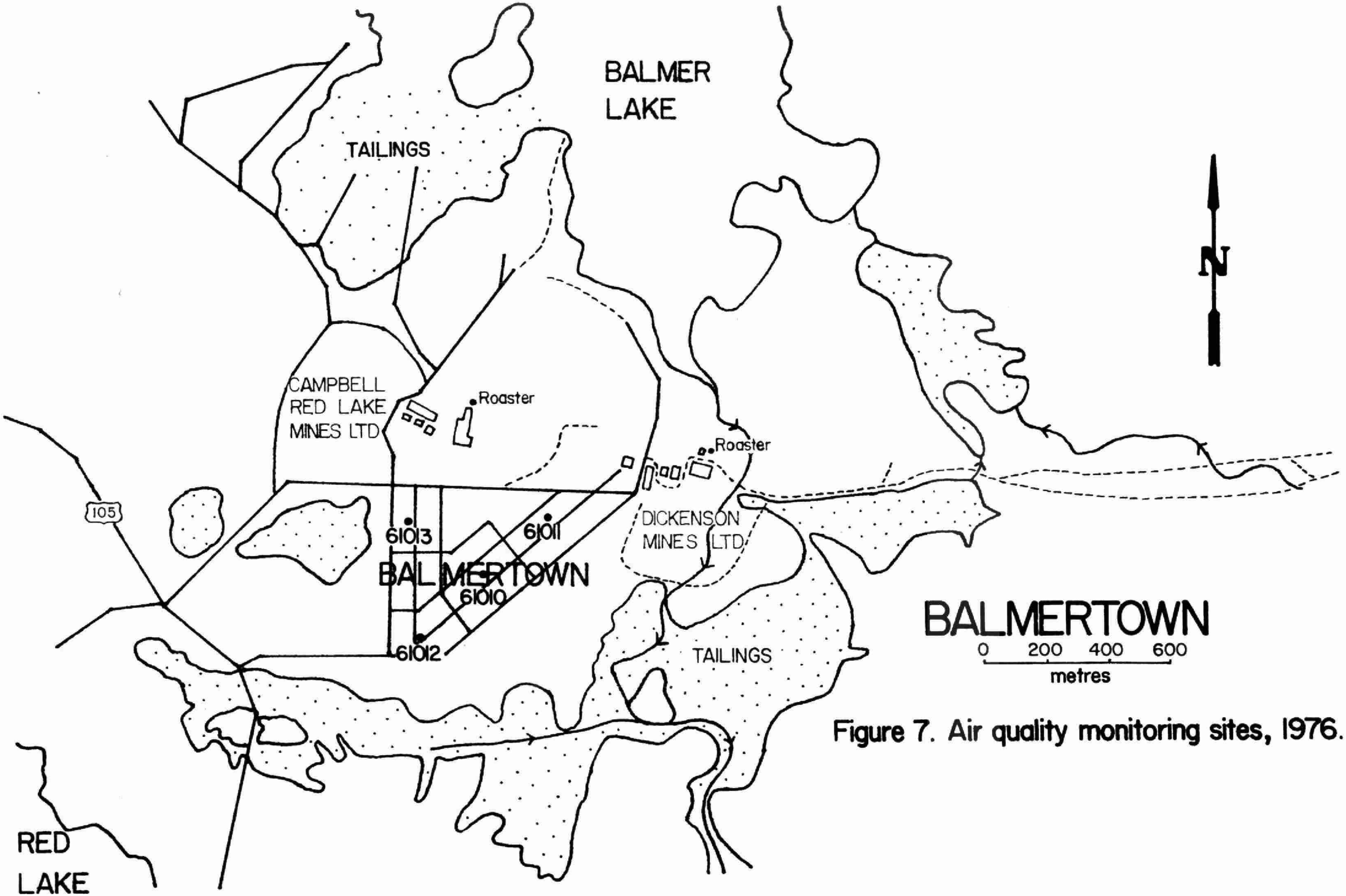

Figure 7. Air quality monitoring sites, 1976.

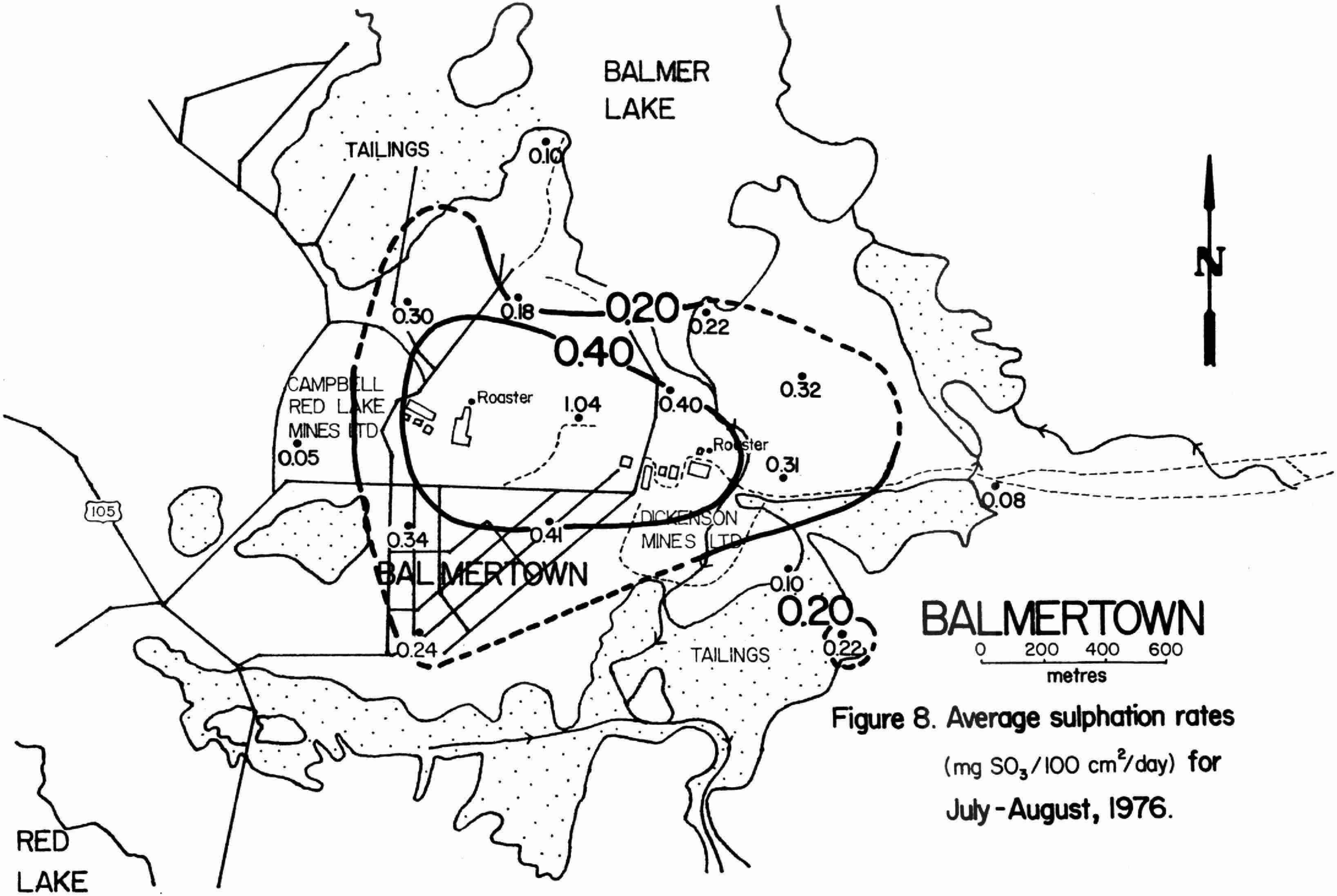

Figure 8. Average sulphation rates ($mg\ SO_3/100\ cm^2/day$) for July-August, 1976.

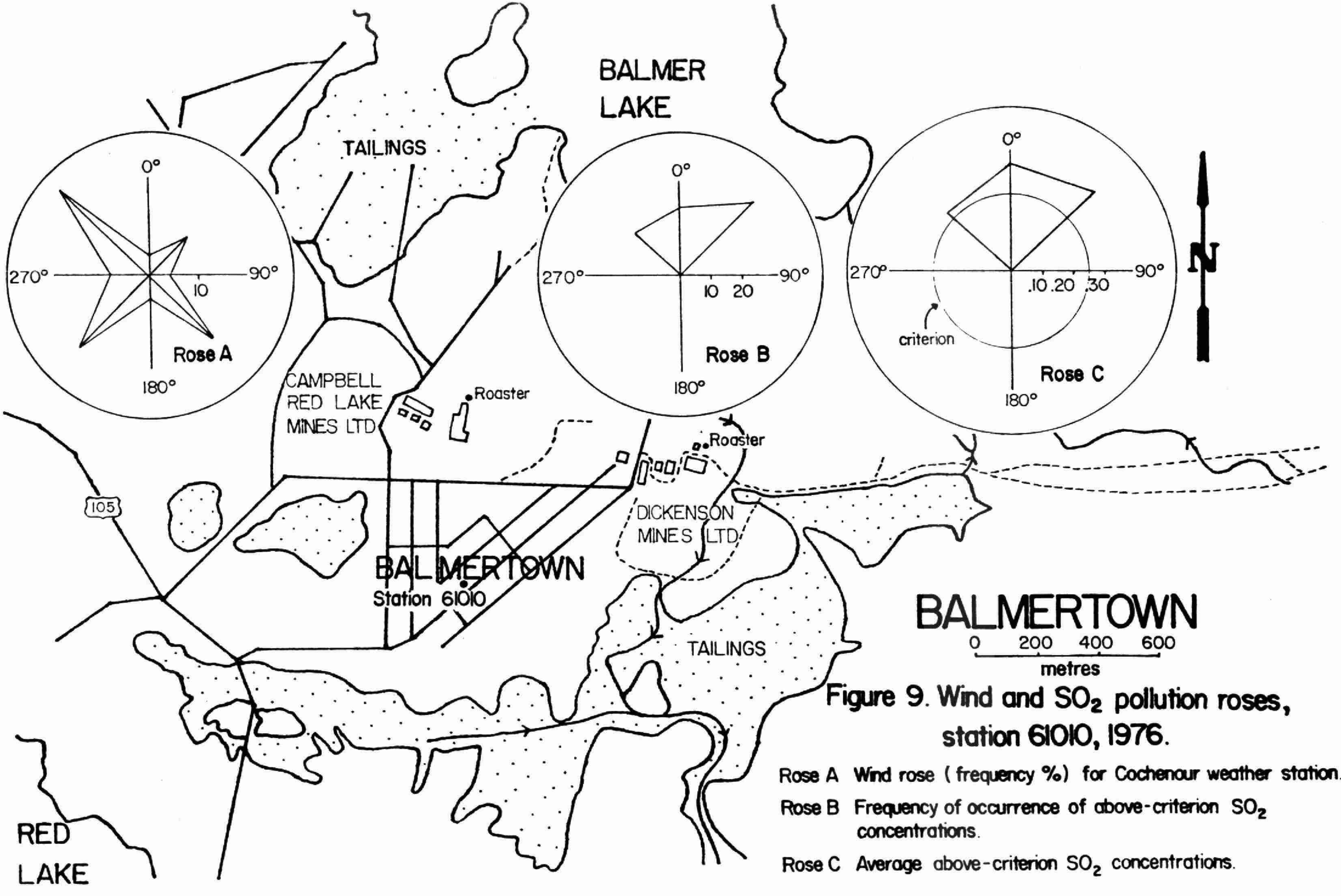

Figure 9. Wind and SO_2 pollution roses, station 61010, 1976.

Rose A Wind rose (frequency %) for Cochenour weather station.

Rose B Frequency of occurrence of above-criterion SO_2 concentrations.

Rose C Average above-criterion SO_2 concentrations.

TABLE 1. Crown condition of trees in observation plots, August, 1976.

Plot	Distance (metres) and direction from Campbell	Distance (metres) and direction from Dickenson	Apparently healthy	Slight dieback	Advanced dieback	Dead
1	415 NNE	830 W	16	1		3
2	880 NNE	1150 NNW	16	2		2
5	350 E	480 W	7	7	5	1
6	740 ESE	280 ESE	20			
7	1470 E	990 E	16	2		2
8	2670 E	1890 E	17	2	1	
9	720 S	830 SW	17	1		2
11	640 WSW	1400 W	15	3	1	1
12	1440 W	2225 W	16	1	2	1
15	27200 SE (control)		20			
16	12500 S (control)		19	1		

TABLE 2. Changes in crown condition of trees in observation plots from July, 1974, to August, 1976.

Plot	Crown condition		
	Unchanged	Improved	Declined
1	16		4
2	15		4
5	11		9
6	20		
7	15	2	3
8	17	1	2
9	18		2
11	15	1	4
12	17		3
15 (control)	20		
16 (control)	20		

TABLE 3. Diameter growth of trees in observation plots from 1973 to 1976.

Plot	Average of 20 trees/plot 1973	1974	1975	1976	Growth cm	%
1	3.9	3.9	4.1	4.1	0.2	5
2	5.8	5.7	5.8	5.9	0.1	2
5	4.3	4.3	4.4	4.3	nil	nil
6	2.7	2.8	3.1	3.3	0.6	22
7	6.1	6.2	6.3	6.6	0.5	8
8	8.9	9.0	9.2	9.2	0.3	3
9	5.6	5.7	5.7	5.8	0.2	4
11	5.3	5.4	5.5	5.6	0.3	6
12	7.8	7.9	8.1	8.1	0.3	4
15 (control)	4.2	4.6	4.9	4.8	0.6	14
16 (control)	3.8	3.9	4.1	4.1	0.3	8

TABLE 4. Levels of arsenic, iron and sulphur in not washed trembling aspen foliage and surface soil, September, 1976.

Site	Distance (metres) and direction from Campbell	Distance (metres) and direction from Dickenson	Concentrations (μg/g, dry weight) Trembling aspen Arsenic	Trembling aspen Iron	Trembling aspen Sulphur	Soil (0-5 cm) Arsenic
10	850 ENE	510 N	6	71	3600	484
13	960 E	200 NE	38	179	3200	283
14	1200 E	500 NE	6	71	2000	811
6	740 ESE	280 ESE	50	1030	3200	1060
15	1310 E	500 E	18	226	2800	790
7	1470 E	990 E	5	129	2700	128
8	2670 E	1890 E	4	49	2000	187
16	1010 ESE	290 SSE	10	102	2000	494
17	1150 ESE	465 SSE	4	59	2100	331
18	1470 SE	900 SSE	7	96	2400	109
19	640 ESE	305 SW	15	218	3500	751
20	625 SE	500 SW	5	62	4200	19
9	735 S	900 SW	6	71	2700	283
24	370 SSE	670 WSW	13	115	3700	602
21	670 SSW	1170 WSW	8	198	2900	135
22	1150 SW	1710 WSW	2	38	2400	246
5	350 E	480 W	18	58	4000	1130
11	640 WSW	1400 W	2	44	1900	341
12	1440 W	2225 W	4	38	1500	46
23	400 NW	1140 WNW	13	91	4500	1440
3	480 ENE	510 NW	8	66	3200	1600
1	415 NNW	830 NW	10	60	3000	1320
4	670 E	225 NNW	13	126	3900	410
2	880 NNE	1150 NNW	6	34	2400	223
25	27200 SE	(control)	<1	55	2200	9
26	12500 S	(control)	<1	40	1900	16

TABLE 5. Total arsenic and water soluble arsenic in soil in relation to total arsenic in trembling aspen foliage.

	Arsenic concentrations (μg/g)		
		Soil (0-5 cm)	
Site	Foliage	Total	Water Soluble
1	10	1320	13
3	8	1600	29
4	13	410	17
5	18	1130	44
6	50	1060	7
13	38	283	3
15	18	790	10
16	10	494	7
19	15	751	12
23	13	1440	31
24	13	602	26

TABLE 6. Comparison between arsenic content (μg/g, dry weight) of not washed trembling aspen foliage for the years 1973 to 1976*.

Site	1972	1973	1974	1975	1976
1	-	-	26	31	10
2	-	-	22	26	6
5	155	554	29	33	18
6	78	404	196	257	50
7	21	81	43	29	5
8	-	-	14	18	4
9	265	407	19	6	6
11	98	108	10	7	2
12	27	41	9	9	4
Controls	<1	8	3	2	<1

*Values for 1972-1974 based on single samples, those for 1975 and 1976 based on triplicate samples.

TABLE 7. Comparison between arsenic levels (μg/g, dry weight) in not washed Manitoba maple and white elm foliage from planted roadside trees*.

Year	Side of tree	Distance (metres) and direction from Dickenson - 525 SW / Campbell - 480 SE	1005 SW / 610 S	1090 SW / 430 SW	8000 SW (control)
1973	Facing	504	734	352	19
	Away	323	432	202	25
1974	Facing	70	36	20	4
	Away	31	21	12	-
1975	Facing	138	76	34	4
	Away	58	46	18	-
1976	Facing	18	12	20	2
	Away	18	9	11	-

TABLE 8. Comparison between average arsenic content (μg/g, dry weight*) in washed vegetables and surface soil (0-5 cm) from three Balmertown gardens, 1973 to 1976**.

		Balmertown				Red Lake			
		1973	1974	1975	1976	1973	1974	1975	1976
Potato	- leaves	-	18	24	15	-	4	2	2
	- tubers	-	2	2	2	-	< 1	< 1	< 1
Beet	- leaves	185	8	8	7	8	< 1	< 1	< 1
	- roots	44	3	9	4	2	< 1	< 1	< 1
Lettuce	- leaves	138	9	18	12	-	2	< 1	< 1
Soil	- garden	-	164	153	64	-	10	10	8
	- lawn	-	567	452	206	-	14	10	9

*Dry Weight:fresh weight ratio is about 10:1.

**Values for 1973 and 1974 based on single samples, those for 1975 and 1976 based on triplicate samples.

TABLE 9. Levels of arsenic, mercury, iron, and pH in snow collected January 27-28, 1976.

Site	Arsenic (μg/l)	Iron (mg/l)	Mercury (μg/l)	pH
1	260	2.1	0.1	3.8
2	290	1.5	< 0.1	3.5
3	230	1.5	< 0.1	3.5
4	260	1.6	0.3	3.5
5	80	0.7	< 0.1	3.5
6	170	0.7	0.3	3.5
7	420	2.3	0.1	3.5
8	150	1.0	5.6	3.7
9	80	0.6	4.0	3.6
10	90	1.1	0.3	3.5
11	350	2.1	0.2	3.5
12	280	2.3	0.1	3.6
13	100	0.8	0.7	3.6
14	60	0.8	0.6	3.6
15	170	1.7	0.2	3.4
16	200	0.6	0.7	3.6
17	< 10	0.2	< 0.1	3.5
18	40	0.4	0.1	3.6
19	200	1.2	0.2	3.5
20	180	3.6	< 0.1	4.5
21	60	0.5	0.1	3.4
22	450	3.0	1.1	3.5
23	190	1.0	0.1	3.3
24	90	0.6	0.1	3.5
Control	< 10	0.2	< 0.1	3.4
Control	< 10	0.6	< 0.1	3.5

TABLE 10. Total dustfall and soluble sulphate in dustfall, Balmertown, 1976.

Station	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
		Total dustfall (tons/square mile/30 days)												
61010	Lassie/Dickenson	1	4	-	12	9	11	-	-	-	-	-	16	9
61011	113 Dickenson Road	-	-	-	13	12	28*	-	13	37	-	11	21	19
61012	Fifth/Dickenson	-	-	-	1	-	23	-	18	-	-	-	-	14
61013	273 Fifth Street	6	3	6	-	21	-	-	-	16	18	10	1	10
		Soluble sulphate (tons/square mile/30 days)												
61010	Lassie/Dickenson	0.1	2.4	-	0.4	0.3	0.9	-	-	-	-	-	1.4	0.9
61011	113 Dickenson Road	-	-	-	1.8	0.6	1.3	-	1.9	2.0	-	0.6	1.5	1.4
61012	Fifth/Dickenson	-	-	-	0.4	-	1.0	-	1.3	-	-	-	-	0.9
61013	273 Fifth Street	0.4	1.2	0.9	-	0.9	-	-	-	0.9	1.1	0.6	0.1	0.8

*Values exceeding criteria of 20 (monthly) or 13 (annual average) are underlined.

TABLE 11. Arsenic in dustfall (lbs/acre/year), Balmertown, 1976.

Station	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
61010	Lassie/Dickenson					0.2	0.2						0.3
61011	113 Dickenson Road					0.3	0.3		0.5	0.7		0.1	0.3
61012	Fifth/Dickenson						0.1		0.5				
61013	273 Fifth Street					0.4				0.2	0.1	$<$ 0.1	0.1

TABLE 12. Sulphation rates (mg SO_3/100 cm^2/day), Balmertown, 1976.

Station	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
61010	Lassie/Dickenson	-	1.44*	.98	1.76	.30	1.12	-	-	.76	.46	.66	.23	.86
61011	113 Dickenson Road	.88	.44	.58	1.64	.66	.52	.49	.35	.50	.38	.44	.49	.61
61012	Fifth/Dickenson	-	.32	.76	.71	.18	.52	.41	.07	.24	.30	.35	.13	.36
61013	273 Fifth Street	.06	.54	-	.87	.26	.26	.19	.48	.28	.18	.22	.08	.31

*Values above criterion (0.70 mg SO_3/100 cm^2/day) are underlined.

TABLE 13. Average hourly sulphur dioxide concentrations (parts per hundred million) in 1976 at station 61010, Balmertown.

Month	Days of data	Frequency distribution (no. of hrs.)						Maximum value	
		0-4	5-10	11-14	15-25	26-39	39	Hourly	Daily
Jan	1	51	1	0	4	4	1	40	10
Feb	7	316	7	3	2	0	0	24	4
Mar	11	284	9	7	4	1	0	31	5
Apr	22	557	35	1	3	1	0	30	4
May	12	250	4	4	15	10	10	53	22
Jun	29	586	19	5	13	15	6	54	30
Jul	31	613	33	9	16	8	2	51	14
Aug	22	507	11	2	6	3	0	36	10
Sep	20	464	6	3	10	9	2	49	14
Oct	20	456	4	2	7	3	2	48	10
Nov	10	261	0	0	0	1	0	28	1
Dec	10	227	2	2	1	0	0	21	2
Year	195	4572	131	38	81	55	23	54	30